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(REV 5-93)

US DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY DOCKET NUMBER  
2001\_0396ATRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. §37109/80/841  
U.S. APPLICATION  
(35 U.S.C. §371)  
NEWInternational Application No.  
PCT/NO99/00293International Filing Date  
September 21, 1999Priority Date Claimed  
October 27, 1998**Title of Invention**

METHOD AND SYSTEM FOR TRANSPORTING A FLOW OF FLUID HYDROCARBONS CONTAINING WATER

**Applicant(s) For DO/EO/US**


Are LUND; David LYSNE; Roar LARSEN; and Kai W. HJARBO

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. §371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. §371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. §371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. §371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. §371(c)(2))
  - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☒ has been transmitted by the International Bureau. - **Attachment "A"**
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. §371(c)(2)). - **Attachment "B"**
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3)).
  - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☐ have been transmitted by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19.
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. §371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. §371(c)(5)).

Items 11. to 14. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98. - **Attachment "C"**
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment. - **Attachment "D"**  
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☒ Other items or information:  
 Cover Letter for Application Filed Without Executed Declaration along with Unexecuted Declaration - Attachment "E".  
 International Preliminary Examination Report (IPER) - Attachment "F"

U.S. APPLICATION NO. <b>09/807841</b> NEW		INTERNATIONAL APPLICATION NO. PCT/NO99/00293		ATTORNEY'S DOCKET NO. 2001 0396A					
15. <input checked="" type="checkbox"/> The following fees are submitted  <b>BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):</b> Neither international preliminary examination fee nor international search fee paid to USPTO and International Search Report not prepared by the EPO or JPO ..... \$1000.00 International Search Report has been prepared by the EPO or JPO ..... \$ 860.00 International preliminary examination fee not paid to USPTO but international search paid to USPTO ..... \$ 710.00 International preliminary examination fee paid to USPTO but claims did not satisfy provisions of PCT Article 33(1)-(4) ..... \$ 690.00 International preliminary examination fee paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) ..... \$ 100.00  <b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>				<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 50%;">CALCULATIONS</th> <th style="width: 50%;">PTO USE ONLY</th> </tr> <tr> <td style="height: 100px;"></td> <td></td> </tr> </table>		CALCULATIONS	PTO USE ONLY		
CALCULATIONS	PTO USE ONLY								
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$					
Claims	Number Filed	Number Extra	Rate						
Total Claims	24 -20 =	4	X \$18.00	\$72.00					
Independent Claims	2 - 3 =	-0-	X \$80.00	\$					
Multiple dependent claim(s) (if applicable)			+ \$270.00	\$					
<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$932.00					
<input type="checkbox"/> Small Entity Status is hereby asserted. Above fees are reduced by 1/2.				\$					
<b>SUBTOTAL =</b>				\$932.00					
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				+	\$				
<b>TOTAL NATIONAL FEE =</b>				\$932.00					
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40 per property +				\$					
<b>TOTAL FEES ENCLOSED =</b>				\$932.00					
				Amount to be refunded	\$				
				Amount to be charged	\$				
a. <input checked="" type="checkbox"/> A check in the amount of <u>\$932.00</u> to cover the above fees is enclosed. A duplicate copy of this form is enclosed. b. <input type="checkbox"/> Please charge my Deposit Account No. 23-0975 in the amount of \$_____ to cover the above fees. A duplicate copy of this sheet is enclosed. c. <input type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>23-0975</u> .  <b>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or          (b)) must be filed and granted to restore the application to pending status.</b>									
19. CORRESPONDENCE ADDRESS   <div style="text-align: center;">   <b>000513</b>          PATENT TRADEMARK OFFICE       </div>			By: <u>Michael S. Huppert</u> Michael S. Huppert, Registration No. 40,268  WENDEROTH, LIND & PONACK, L.L.P. 2033 "K" Street, N.W., Suite 800 Washington, D.C. 20006-1021 Phone: (202) 721-8200 Fax: (202) 721-8250  April 19, 2001						

[CHECK NO. 44042]

[2001\_0396A]

## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of :  
Are LUND et al. : Attn: BOX PCT  
Serial No. NEW : Docket No. 2001\_0396A  
Filed April 19, 2001 :

METHOD AND SYSTEM FOR TRANSPORTING  
A FLOW OF FLUID HYDROCARBONS  
CONTAINING WATER  
[Corresponding to PCT/NO99/00293  
Filed September 21, 1999]

THE COMMISSIONER IS AUTHORIZED  
TO CHARGE ANY DEFICIENCY IN THE  
FEE FOR THIS PAPER TO DEPOSIT  
ACCOUNT NO. 23-0975.

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**PRELIMINARY AMENDMENT**

Assistant Commissioner for Patents,  
Washington, DC 20231

Sir:

**Prior to initial examination of the above-identified new PCT application, kindly amend the application as follows:**

**IN THE CLAIMS:**

**Kindly amend claims 3-10 and 14-18 as follows:**

3.(Amended) The method of claim 1, characterized in that desired chemicals are added upstream to the reactor.

4.(Amended) The method of claim 1, characterized in that the flow of fluid hydrocarbons is subjected to a mixing operating before introduction into the reactor to disperse the water present as droplets in the fluid hydrocarbon phase.

5.(Amended) The method of claim 1, characterized in that said second flow from the separator is mixed with wet gas before it is conveyed to the pipeline.

6.(Amended) The method of claim 1, characterized in that the method is performed at the sea bottom.

7.(Amended) The method of claim 1, characterized by using an uninsulated pipe as heat exchanger when the surrounding temperature is sufficiently low.

8.(Amended) The method of claim 1, characterized in that the fluid hydrocarbons are hydrocarbon gas.

9.(Amended) The method of claim 1, characterized in that the hydrocarbon flow is conveyed through a choke which is arranged upstream of the reactor or is a part of the reactor.

10.(Amended) The method of claim 1, characterized in that the flow from the reactor conveyed through a first separator to be separated in a hydrocarbon gas flow and a flow which is subsequently subjected to separation in a second separator into said first and second flow.

14.(Amended) The system of claim 12, characterized in that it includes a mixer (5) between the first heat exchanger (4) and the reactor (6).

15.(Amended) The system of claim 12, characterized in that it includes means (2) for adding chemicals to the flow.

16.(Amended) The system of claim 12, characterized in that it includes means (12) between the separator and the pipeline for mixing the flow from the separator (8) with wet gas (11) before said flow enters the pipeline (13).

17.(Amended) The system of claim 12, characterized in that it includes a separator (14) between the second heat exchanger (7) and the separator (8) for recovering hydrocarbon gas from the flow.

18.(Amended) The system of claim 12, characterized in that it comprises means (16) for adding cooled condensate under pressure to the line (9) from the separator (8) to the reactor (9).

**Kindly add the following new claims:**

19.(NEW) The method of claim 2, characterized in that desired chemicals are added upstream to the reactor.

20.(NEW) The method of claim 2, characterized in that the flow of fluid hydrocarbons is subjected to a mixing operating before introduction into the reactor to disperse the water present as droplets in the fluid hydrocarbon phase.

21.(NEW) The method of claim 3, characterized in that the flow of fluid hydrocarbons is subjected to a mixing operating before introduction into the reactor to disperse the water present as droplets in the fluid hydrocarbon phase.

22.(NEW) The system of claim 13, characterized in that it includes a mixer (5) between the first heat exchanger (4) and the reactor (6).

23.(NEW) The system of claim 13, characterized in that it includes means (2) for adding chemicals to the flow.

24.(NEW) The system of claim 14, characterized in that it includes means (2) for adding chemicals to the flow.

"The system of claim 14, characterized in that it includes means (2) for adding chemicals to the flow."

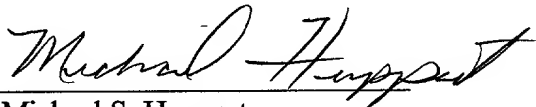
**REMARKS**

The present Preliminary Amendment is submitted to delete the multiple dependencies of claims, 3-10 and 14-18, thereby placing such claims in condition for examination and reducing the required PTO filing fee.

Copies of the amended portion of the claims with changes marked therein is attached and entitled "*Version with Markings to Show Changes Made.*"

Respectfully submitted,

Are LUND et al.

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April 19, 2001

P A T E N T   C L A I M S

1. Method for transporting a flow of fluid hydrocarbons containing water through a treatment and transportation system including a pipeline, characterized  
5 in that the flow of fluid hydrocarbons is introduced into a reactor where it is mixed with particles of gas hydrates which are also introduced into said reactor, the effluent flow of hydrocarbons from the reactor is cooled in a heat exchanger to ensure that all water present therein is in the form of gas hydrates, said flow is then treated in a separator to be separated into a first flow and a second flow, said  
10 first flow having a content of gas hydrate is recycled to the reactor to provide the particles of gas hydrates mentioned above, and said second flow is conveyed to a pipeline to be transported to its destination.
2. The method of claim 1, characterized in that the flow of fluid hydrocarbons  
15 is cooled in a first heat exchanger before being introduced into the reactor.
3. The method of any of claims 1 and 2, characterized in that desired chemicals are added upstream to the reactor.
- 20 4. The method of any of claims 1-3, characterized in that the flow of fluid hydrocarbons is subjected to a mixing operating before introduction into the reactor to disperse the water present as droplets in the fluid hydrocarbon phase.
5. The method of any of claims 1-4, characterized in that said second flow  
25 from the separator is mixed with wet gas before it is conveyed to the pipeline.
6. The method of any of claims 1-5, characterized in that the method is performed at the sea bottom.
- 30 7. The method of any of claims 1-6, characterized by using an uninsulated pipe as heat exchanger when the surrounding temperature is sufficiently low.



8. The method <sup>of</sup> ~~of any~~ <sup>of</sup> ~~claims 1-7~~ characterized in that the fluid hydrocarbons are hydrocarbon gas.

9. The method ~~of any~~ <sup>of</sup> ~~claims 1-8~~ characterized in that the hydrocarbon flow is conveyed through a choke which is arranged upstream of the reactor or is a part of the reactor.

10. The method ~~of any~~ <sup>of</sup> ~~claims 1-9~~ characterized in that the flow from the reactor conveyed through a first separator to be separated in a hydrocarbon gas flow and a flow which is subsequently subjected to separation in a second separator into said first and second flow.

11. The method of claim 10, characterized in that cooled condensate under pressure is added to said first flow which is recycled to the reactor.

12. System for treatment and transportation of a flow of fluid hydrocarbons containing water, characterized in that it includes the following elements listed in the flow direction and connected with each other:

connection to a hydrocarbon source (1),  
a first heat exchanger (4),  
a reactor (6),  
a second heat exchanger (7),  
a separator (8), and  
a pipeline (13);  
and in addition a line (9) which leads from the separator (8) to the reactor (6) and is provided with a pump (10) adapted to recycle material from the separator (8) back to the reactor (6).

13. The system of claim 12, characterized in that the inside of the reactor (6) is coated with a water-repellent material.

14. The system of any of claims ~~12~~ and 13, characterized in that it includes a mixer (5) between the first heat exchanger (4) and the reactor (6).

15. The system of any of claims ~~12~~ 14, characterized in that it includes means  
5 (2) for adding chemicals to the flow.

16. The system of any of claims ~~12~~ 15, characterized in that it includes means  
(12) between the separator and the pipeline for mixing the flow from the separator  
(8) with wet gas (11) before said flow enters the pipeline (13).

10

17. The system of any of claims ~~12~~ 16, characterized in that it includes a  
separator (14) between the second heat exchanger (7) and the separator (8) for  
recovering hydrocarbon gas from the flow.

15

18. The system of any of claims ~~12~~ 17, characterized in that it comprises  
means (16) for adding cooled condensate under pressure to the line (9) from the  
separator (8) to the reactor (9).

"Method and system for transporting a flow of fluid hydrocarbons containing water."

The present invention relates to a method and a system for transporting a flow of fluid (i.e. liquid or gaseous) hydrocarbons containing water. In the method said flow is transported through a treatment and transportation system including a pipeline.

The search for new oil or gas resources has now reached a stage where it is moving away from relatively easily accessible continental waters, and towards deeper waters. This trend is currently most visible in the Gulf of Mexico, but also offshore Norway, any large oil or gas discoveries in the future are primarily expected in deep waters ( $\geq 4-500$  m). This development gives rise to several technological challenges. However, solutions based on sub-sea installations and long distance transport to already existing production and processing facilities have already been in use for some time in the North Sea, especially in connection with economically marginal fields in the vicinity of older platforms. This technology will become steadily more prevalent in new field developments for deep water, but also in the increasing number of smaller projects in already developed areas.

Traditionally, in the North Sea, use of sub-sea templates and pipeline transport of the well-stream in multiphase pipelines has been restricted to a few tens of kilometers. However, better simulation and design tools, better equipment for partial separation, as well as pumping and boosting, has now led to solutions of this kind being used with transfer distances of up to 110 km in the Gulf of Mexico.

The single most challenging problem for these future trends in oil and gas exploration, is the presence of natural gas hydrates in transport pipelines and equipment. Natural gas hydrate is an ice-like compound consisting of light hydrocarbon molecules encapsulated in an otherwise unstable water crystal structure. These hydrates form at high pressures and low temperatures wherever a suitable gas and free water are present. These crystals can deposit on pipeline walls and in equipment, and in the worst case lead to complete plugging of the system. Costly and time-consuming procedures may be needed to restore flow

again. In addition to the mere economic consequences, there are also numerous hazards connected to hydrate formation and removal, and there are known instances of pipeline ruptures and loss of human lives due to gas hydrates in pipelines. Although hydrate is generally thought of as a problem mostly for gas production, there is now ample evidence that it is also a significant problem for condensate and oil production systems.

There are several available methods for dealing with hydrate problems. So far, the usual philosophy has been to take steps to avoid any hydrate formation at all. This can be achieved by keeping pressures low (often not possible from flow considerations), keeping temperatures high (usually by insulating - which does not protect against shutdowns or long distances), removing the water completely (costly equipment and difficult), or by adding chemicals that suppress hydrate formation thermodynamically. Insulation is very often used, but is not sufficient alone. Chemical addition, specifically methanol (MeOH) or ethylene glycol (EG), is therefore the most widespread hydrate control mechanism in the industry today. These antifreezes expand the pressure-temperature-area of safe operation, but are needed in large quantities - 50% of the total liquid fraction is not unusual in water-rich production. The use of MeOH in the North Sea may approach 3 kg per 1000 Sm<sup>3</sup> of gas extracted. The need for such large amounts places severe demands on logistics of transportation, storage and injection in offshore facilities with a deficiency of space. The transport and injection processes for MeOH in particular, are also plagued with numerous leakages and spills.

Inhibitor chemicals of different types are not only used in the pipeline transport and processing areas, but also extensively in drilling operations and wells.

Partly due to the huge amounts and large costs involved in using traditional inhibitors like MeOH, there has over the last decade been extensive efforts devoted to finding chemicals which may be effective at controlling hydrates at much lower concentrations.

Many oil companies and research institutes have contributed to this effort, and at present, the results are divided into three main categories: kinetic inhibitors, dispersants, and modifiers. Kinetic inhibitors have an affinity for the crystal

surface, and thereby can be used to prevent hydrate crystal growth. Dispersants act as emulsifiers, dispersing water as small droplets in the hydrocarbon liquid phase. This limits the possibilities for hydrate particles to grow large or to accumulate. The modifiers are to a certain extent a combination of the two other methods, attaching to the crystal surface, but also functioning as a dispersant in the liquid hydrocarbon phase. These methods have been somewhat successful, although there are practical drawbacks to most of them. The most significant problem, however, seems to be that all the best chemical additives thus far produced have significant negative environmental effects, and that no solution to this problem seems imminent - at least in the open literature.

There is growing understanding in the oil and gas industry that hydrate particles in a flow situation are not necessarily a problem per se. If the particles do not deposit on walls or equipment, and do not have a large impact on flow characteristics (i.e. their concentration is not too large), they simply flow with the rest of the fluids, without creating a problem situation. The challenge will therefore be to achieve this situation in a controlled manner, and making sure that hydrate formation does not take place randomly throughout the flow system.

Another aspect which will definitely be affected by the present invention, is corrosion in sub-sea pipelines. Huge sums of money and large resources in material and time are involved in protecting pipelines from corrosion, e.g. through conservative design (pipeline wall thickness, steel quality) and through the use of corrosion inhibitors. Not necessarily used in the same amounts per pipeline as the hydrate inhibitors, the total amounts of chemicals (sometimes with environmentally highly adverse effects) are huge, as they are used in such a great number of pipelines. Much of this corrosion is connected with free water, and successful results of the present invention may reduce this problem significantly.

The present invention provides a method for transporting a flow of fluid hydrocarbons containing water through a treatment and transportation system including a pipeline. According to the invention the flow of fluid hydrocarbons is introduced into a reactor where it is mixed with particles of gas hydrates which are also introduced into said reactor, the effluent flow of hydrocarbons from the reactor is cooled in a heat exchanger to ensure that all water present therein is in

the form of gas hydrates, said flow is then treated in a separator to be separated into a first flow and a second flow, said first flow having a content of gas hydrates is recycled to the reactor to provide the particles of gas hydrates mentioned above, and said second flow is conveyed to a pipeline to be transported to its destination.

Said flow of fluid hydrocarbons will normally come from a drilling hole well and will be relatively warm and will be under pressure. It is generally preferred to cool the flow of fluid hydrocarbons in a first heat exchanger before introducing said flow into the above-mentioned reactor.

It is sometimes desirable to add certain chemicals to the flow upstream to the reactor.

Before the flow enters the reactor it may advantageously be subjected to a mixing operation in order to disperse the water present as droplets in the fluid hydrocarbon phase.

The second flow from the separator may be mixed with wet gas in a mixing vessel before the flow is conveyed to the pipeline for further transport.

The method is particularly applicable in those cases where transportation takes place at a relatively low temperature, both on land in a cool climate and at the sea bottom.

When the surroundings are rather cool, one or more of the heat exchangers used may be an uninsulated pipe. When the surrounding temperature is sufficiently low, this will provide satisfactory cooling without any further cooling medium.

The invention also provides a system for treatment and transportation of a flow of fluid hydrocarbons containing water. The system includes the following elements listed in the flow direction and connected with each other so that the hydrocarbons may pass through the entire system (the numerals in parenthesis refer to the enclosed drawings which serve as illustration only):

connection to a hydrocarbon source (1),

a first heat exchanger (4),

a reactor (6),

a second heat exchanger (7),

a separator (8), and

a pipeline (13);

and in addition a line (9) which leads from said separator (8) to the reactor (6) and is provided with a pump (10) adapted to recycle material from the separator (8)

5 back to the reactor (6). The pump may be any kind of pump, but it may advantageously be of a type which crushes the hydrate particles into more and smaller particles with a larger total crystal surface.

The inside of the system, in particular the inside of the reactor may be coated with a water repellent material. Tubing may also advantageously be  
10 provided with such a coating material.

The system preferably includes a mixer or a choke (5) upstream to the reactor (6).

In many cases it is advantageous to add different chemicals to the flow of hydrocarbons, in particular during start-up and when changes are made in the  
15 operation. The system accordingly contains for such purpose means for adding chemicals to the flow.

In the following the present method and system will be described in more detail, again with reference to the drawings.

In a first embodiment (fig. 1) warm oil/condensate/hydrate-forming  
20 components and water under pressure (1) are mixed with any desired chemicals (2) in a mixing means (3). If much water is initially present, some of the water is preferably separated off before mixing said components and water with chemicals. The chemicals in question may be nucleating agents for hydrate, emulsion-  
breakers/-formers, wax inhibitors or any type of chemical used for  
25 transportation/storage of said fluid. The chemicals used should be acceptable for the environment and should generally be used during start-up only. In any case the consumption of chemicals will be much lower during continuous operation than previous transportation/storage systems, and chemicals may even be left out completely.

30 The fluid from the mixer (3) may be cooled to a temperature just above the hydrate equilibrium curve of the fluid (the melting curve of hydrate) in a heat

exchanger (4). At the bottom of the ocean said heat exchanger may be an uninsulated tube, or it may be any type of cooler.

The fluid from the heat exchanger (4) is conveyed to a mixer (5) which may be any type of mixer. The mixer distributes the water in the fluid hydrocarbons as droplets. It should be noted that the mixer is not strictly necessary. The question whether or not a mixing operation is necessary depends on the characteristics of the fluid, i.e. the ability of the fluid to distribute the water as droplets in the fluid without any other influence than the turbulence which occurs when the fluid flows through a pipe.

The fluid from the mixer (5) is conveyed into a reactor (6), where it is mixed with cold (temperature below the melting temperature of the gas hydrate) fluid from a separator (8) (see below). Said cold fluid from the separator (8) contains small particles of dry hydrate.

The water which is present in the fluid from the mixer (5) will moisten dry hydrate from the separator (8) in the reactor (6). In the reactor (6) the water which moistens the dry hydrate will immediately be converted to hydrate. New hydrate which is formed will accordingly increase the size of the hydrate particles from the separator (8) and also form new small hydrate particles when larger hydrate particles break up. New hydrate seed may also be formed elsewhere in the reactor (6).

Sub-cooling (the actual temperature being lower than the hydrate equilibrium temperature) of the fluid is required to form hydrates. The necessary extent of sub-cooling for formation of hydrate in the reactor (6) is accomplished by adding sufficient cold fluid from the separator (8). Cooling may also come from the reactor walls of the reactor (6) or from separate cooling ribs in said reactor. Undesired fouling or formation of deposits in the reactor (6) may be avoided by coating all surfaces with a water-repellent coating.

From the reactor (6) the fluid is cooled down in a second heat exchanger (7). At the bottom of the ocean said cooler may be an uninsulated pipe. The heat exchanger (7) may also be any type of cooler which even may be integrated as a part of the reactor (6).



In the separator (8) some of the total amount of hydrate particles and excess fluid are separated from the rest and conveyed out to a pipeline (13) or first through a mixing means (12) to be mixed with wet gas (11) before entering the pipeline (13).

Residual amounts of the total amount of hydrate particles and residual fluid from the separator (8) are recycled through a line (9) by means of a pump (10) back to the reactor (6). The separator (8) may be any type of separator. Similarly, the pump (10) may be any type of pump, but it is important that it can handle the hydrate particles. It may advantageously be of a type which crushes the hydrate particles into more and smaller particles with a larger total crystal surface. A further cooler may be included in the line (9) either before or behind the pump (10).

Wet gas (11) under pressure may be mixed with the flow of fluid from the separator (8) in a mixing means (12). Free water in the wet gas is absorbed by the dry hydrate from the separator (8) in the mixing means (12). In the mixing means (12) the water which moistens the dry hydrate will readily be converted to hydrate. The new hydrate formed will then increase the size of the hydrate particles from the separator (8) and may also form new small hydrate particles when larger hydrate particles are broken apart. New hydrate seed may also be formed elsewhere in the mixing means (12). At the outlet of the mixing means (12) connected to the pipeline (13) all free water has been converted to hydrate.

At the beginning of the pipeline, either sub-sea at a wellhead template, or onboard a minimum processing platform, water separation is expected to be efficient enough so that after cooling and condensation, no more than 5-10 vol% water is present in the fluid stream.

After this separation stage, the fluids are cooled rapidly towards hydrate stability temperatures in exposed (uninsulated) pipes of the necessary length. The phases are also mixed, to provide a large interfacial surface area. Minute amounts of chemicals may be needed at this stage, e.g. in connection with a start-up situation. A mixer will disperse the water as droplets. Upon next entering the hydrate reactor part of the system, hydrate particles and a cold fluid stream are mixed in from a downstream separator. Water wetting of the hydrate particles will

take place, and hydrate growth will therefore mainly be from existing particles and outwards. The hydrate formation process is thus aided by the addition of cold fluid (inside the stable hydrate pressure-temperature region), and - most important - the already present hydrate particles. Further cooling takes place through the reactor.

5 According to a second embodiment (see fig. 2) the fluid hydrocarbon is preferably a wet hydrocarbon gas. The method of this embodiment is particularly applicable at the sea bottom.

To a great extent the discussion of the first embodiment above will also apply to this second embodiment. In the following, particularly those features  
10 which are more or less different will be discussed.

Warm hydrocarbon gas (1) under pressure is mixed with any desired chemicals (2) in a mixing means (3). Chemicals may also be added to the system in the reactor (6).

The flow from the mixer (3) may be cooled to a temperature just above the  
15 hydrate equilibrium curve of the flow (the melting curve of hydrate) in a heat exchanger (4) and/or through a choke (5) which may be a part of the reactor (6). At the bottom of the ocean said heat exchanger may be an uninsulated tube, or it may be any type of cooler.

The flow from the choke (5) is conveyed into the reactor (6), where it is  
20 mixed with cold (temperature below the melting temperature of the gas hydrate) fluid from a second separator (8) (see below). Said cold fluid from the separator (8) contains small particles of dry hydrates.

Free water and water condensing from hydrocarbon gas in the flow from the choke (5) will moisten dry hydrate from the separator (8) in the reactor (6). In  
25 the reactor (6) the water which moistens the dry hydrate will immediately be converted to hydrate. New hydrate which is formed will accordingly increase the size of the hydrate particles from the separator (8) and also form new small hydrate particles when larger hydrate particles break up. New hydrate seed may also be formed elsewhere in the reactor (6).

30 In a first separator (14) hydrocarbon gas is separated from the flow and conveyed out to a pipeline (15). The separator (14) may be any type of separator.

The rest of the flow is conveyed to the second separator (8) where some of the total amount of hydrate particles and excess fluid are separated from the rest and conveyed out to a pipeline (13).

Residual amounts of the total amount of hydrate particles and residual fluid  
5 from the separator (8) are recycled through a line (9) by means of a pump (10) back to the reactor (6). The separator (8) may be any type of separator. Similarly, the pump (10) may be any type of pump, but it is important that it can handle the hydrate particles.

Additional cooled condensate under pressure may be added (16) to said  
10 recycled flow in order to dilute the hydrate particle concentration and as a cooling media. The addition may be made at any point between heat exchanger (7) and reactor (6).

Hot hydrocarbon gas, either sub-sea at a wellhead template, or from a minimum processing platform, is expected to be saturated with water vapour at  
15 the beginning of the pipeline.

After the wellhead template or platform, the flow is cooled rapidly towards hydrate stability temperature in exposed (uninsulated) pipes of the necessary length or through a choke. Minute amounts of chemicals may be needed at this stage, e.g. in connection with a start-up situation. Upon entering the hydrate  
20 reactor part of the system, hydrate particles and cold fluid stream, are mixed in from a downstream separator. Water vapour from the hydrocarbon gas phase will condensate and water wetting of the hydrate particles will take place. From this stage hydrate growth will therefore mainly take place from existing particles. The hydrate formation process is thus aided by the addition of cold fluid (inside the  
25 stable hydrate pressure-temperature region), and-most important – the already present hydrate particles. Further cooling takes place through the reactor. Hydrocarbon fluid condensed from the cooled hydrocarbon gas will add to the fluid in the reactor.

A further, general discussion of the present invention is given in the  
30 following.

Free water in the pipeline proper will tend to act as a "bonding agent" between hydrate and pipe walls. The inner surface of the hydrate reactor can be treated to become non-wetting with respect to water.

All of the water in the stream will be converted to dry hydrate particles by the time it reaches the end of the hydrate reactor. Before the stream reaches the downstream separator it is cooled close to ambient temperature in exposed (uninsulated) pipes of necessary length. In the separator some of the cold hydrocarbon fluids and dry hydrate particles are taken out, and re-injected at the reactor inlet, as described above.

If injection of wet gas (from the initial separation stage) is desirable, it may take place after the separation/recirculation point (8), into the stream with fully converted hydrates. These fluids may then flow through a similar hydrate reactor to achieve full conversion before the main pipeline. However, no separation and recirculation is viewed as necessary for this stage.

The main pipeline starts immediately after the separator or the wet gas hydrate reactor.

With the water being in hydrate form, and the hydrate particles being dry (no excess water) it has been known experimentally in flow loops with both model systems and with real field fluids and pressures and temperatures, that the resulting hydrate powder is easily transportable with the liquid flow. These tests also indicated that the particles will not aggregate or deposit on pipe walls or equipment - not even in the case of longtime shut-downs. This particular phenomenon has been studied by the inventors for several years. It is also a great advantage of the present invention that the absence of free water will reduce the risk of corrosion in pipelines and other installations.

The hydrate powder will not melt back to free the water and natural gas until temperatures rise or pressures become too low - which in reality will be at the end of the transport pipe, where the process will not be problematic. The powder can be mechanically separated from the bulk liquid phase by a sieve (unlike dispersant-induced emulsions which are often difficult to break). Another method would be to melt the hydrates in a separator where the residence time is long enough for the emerging water to separate out from the hydrocarbon liquids.

Depending on the fluid system, the particle density may even deviate enough from the bulk liquid so that the particles may easily be separated off.

The present invention is expected to create considerable positive environmental effects. The development of a safe and efficient way to transport free water in the form of hydrate particles will dramatically reduce the need for a host of different chemical additives which are used today, both hydrate and corrosion inhibitors. This will impact all aspects of the hydrocarbon production process, from working conditions on production and processing facilities, to the effect on the environment through leaks, accidental discharges or injection system malfunctioning.

A secondary, but no less important, environmental effect will be the improved safety aspects in pipeline operation: with the hydrate plugging and corrosion risks minimized, the danger of pipeline ruptures and large-scale blowouts will also be lowered. It should also be noted that a pipeline in thermal equilibrium with its surroundings will be safer with respect to melting of hydrates in the surrounding sediments which may induce instabilities (settling and landslides). This aspect is in addition to the fact that a cold fluid stream without temperature-induced changes in the fluid composition and properties makes the whole pipeline a more well-defined system to operate. This will not cause additional problems in itself, as pipeline transport over any significant distance will eventually reach ambient temperature also in traditional transport solutions.

The very limited use of chemicals according to the present invention also has the effect that the flow of fluid hydrocarbons is more suitable for its final use than known from the prior art. Thus, e.g. antifreeze such as methanol may have to be removed before the hydrocarbons are used in different processes, such as for polymerization purposes. Such removal is generally very costly.

PATENT CLAIMS

1. Method for transporting a flow of fluid hydrocarbons containing water through a treatment and transportation system including a pipeline, characterized in that the flow of fluid hydrocarbons is introduced into a reactor where it is mixed with particles of gas hydrates which are also introduced into said reactor, the effluent flow of hydrocarbons from the reactor is cooled in a heat exchanger to ensure that all water present therein is in the form of gas hydrates, said flow is then treated in a separator to be separated into a first flow and a second flow, said first flow having a content of gas hydrate is recycled to the reactor to provide the particles of gas hydrates mentioned above, and said second flow is conveyed to a pipeline to be transported to its destination.
2. The method of claim 1, characterized in that the flow of fluid hydrocarbons is cooled in a first heat exchanger before being introduced into the reactor.
3. The method of any of claims 1 and 2, characterized in that desired chemicals are added upstream to the reactor.
4. The method of any of claims 1-3, characterized in that the flow of fluid hydrocarbons is subjected to a mixing operating before introduction into the reactor to disperse the water present as droplets in the fluid hydrocarbon phase.
5. The method of any of claims 1-4, characterized in that said second flow from the separator is mixed with wet gas before it is conveyed to the pipeline.
6. The method of any of claims 1-5, characterized in that the method is performed at the sea bottom.
7. The method of any of claims 1-6, characterized by using an uninsulated pipe as heat exchanger when the surrounding temperature is sufficiently low.

8. The method of any claims 1-7, characterized in that the fluid hydrocarbons are hydrocarbon gas.

9. The method of any of claims 1-8, characterized in that the hydrocarbon flow is conveyed through a choke which is arranged upstream of the reactor or is a part of the reactor.

10. The method of any of claims 1-9, characterized in that the flow from the reactor conveyed through a first separator to be separated in a hydrocarbon gas flow and a flow which is subsequently subjected to separation in a second separator into said first and second flow.

11. The method of claim 10, characterized in that cooled condensate under pressure is added to said first flow which is recycled to the reactor.

12. System for treatment and transportation of a flow of fluid hydrocarbons containing water, characterized in that it includes the following elements listed in the flow direction and connected with each other:

connection to a hydrocarbon source (1),

a first heat exchanger (4),

a reactor (6),

a second heat exchanger (7),

a separator (8), and

a pipeline (13);

and in addition a line (9) which leads from the separator (8) to the reactor (6) and is provided with a pump (10) adapted to recycle material from the separator (8) back to the reactor (6).

13. The system of claim 12, characterized in that the inside of the reactor (6) is coated with a water-repellent material.

14. The system of any of claims 12 and 13, characterized in that it includes a mixer (5) between the first heat exchanger (4) and the reactor (6).

15. The system of any of claims 12-14, characterized in that it includes means (2) for adding chemicals to the flow.

16. The system of any of claims 12-15, characterized in that it includes means (12) between the separator and the pipeline for mixing the flow from the separator (8) with wet gas (11) before said flow enters the pipeline (13).

17. The system of any of claims 12-16, characterized in that it includes a separator (14) between the second heat exchanger (7) and the separator (8) for recovering hydrocarbon gas from the flow.

18. The system of any of claims 12-17, characterized in that it comprises means (16) for adding cooled condensate under pressure to the line (9) from the separator (8) to the reactor (9).



Fig. 1

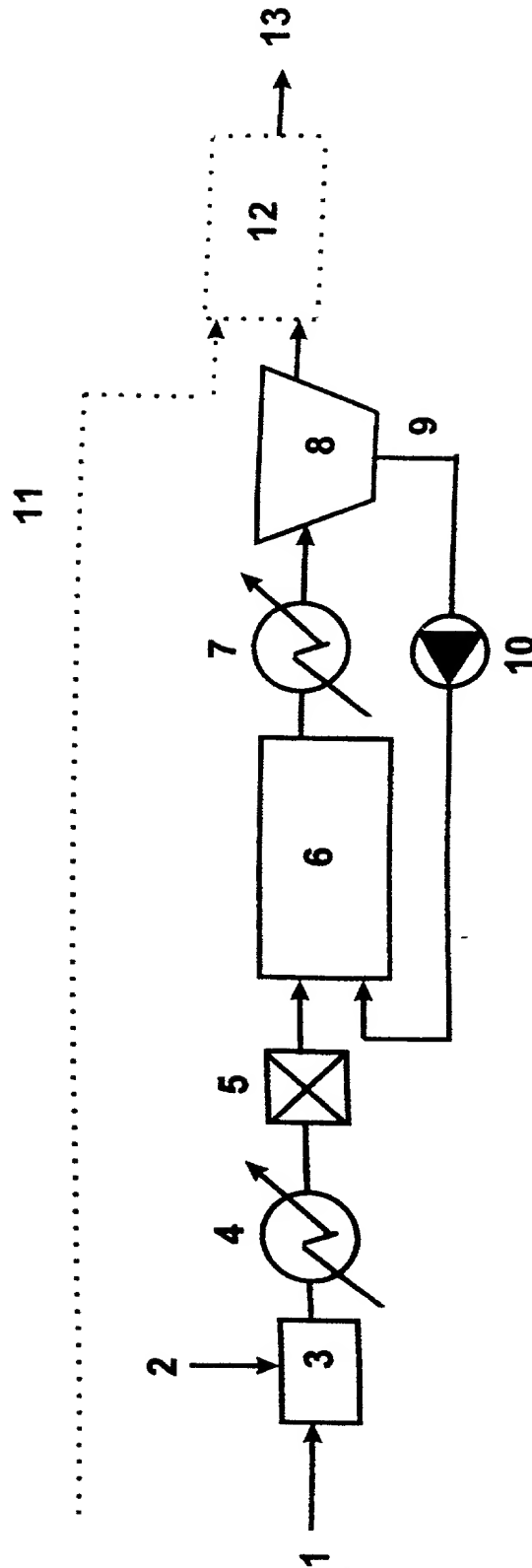
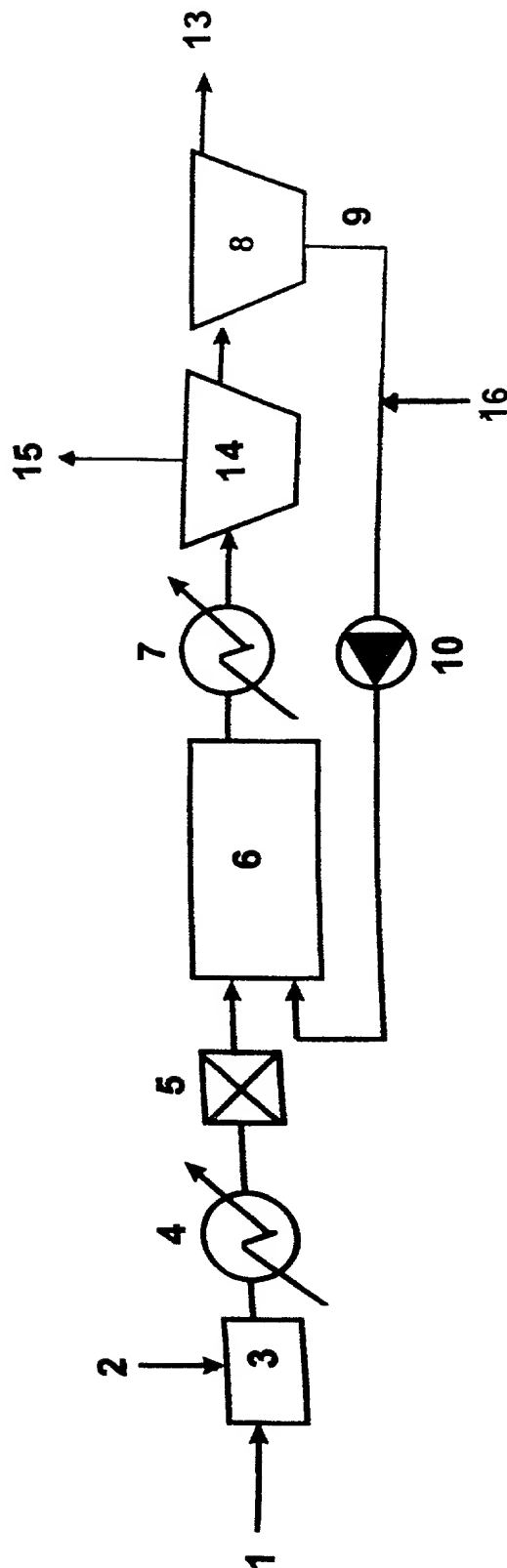


Fig. 2



Rev. 3-21-01

Effective March 1998

**DECLARATION AND POWER OF ATTORNEY FOR U.S. PATENT APPLICATION**

(X) Original    () Supplemental    () Substitute    () PCT    () DESIGN

As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that I verily believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Title: METHOD AND SYSTEM FOR TRANSPORTING A FLOW OF FLUID HYDROCARBONS CONTAINING WATER

of which is described and claimed in:

() the attached specification, or

() the specification in application Serial No. \_\_\_\_\_, filed April 19, 2001, and with amendments through \_\_\_\_\_, or(X) the specification in International Application No. PCT/NO99/00293, filed September 21, 1999, and as amended on (if applicable).

I hereby state that I have reviewed and understand the content of the above-identified specification, including the claims, as amended by any amendment(s) referred to above.

I acknowledge my duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim priority benefits under Title 35, United States Code, §119 (and §172 if this application is for a Design) of any application(s) for patent or inventor's certificate listed below and have also identified below any application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:


COUNTRY	APPLICATION NO.	DATE OF FILING	PRIORITY CLAIMED
Norway	NO 1998 5001	October 27, 1998	YES

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose information material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

APPLICATION SERIAL NO.	U.S. FILING DATE	STATUS: PATENTED, PENDING, ABANDONED

6 And I hereby appoint Michael R. Davis, Reg. No. 25,134; Matthew M. Jacob, Reg. No. 25,154; Warren M. Cheek, Jr., Reg. No. 33,367; Nils Pedersen, Reg. No. 33,145; Charles R. Watts, Reg. No. 33,142; and Michael S. Huppert, Reg. No. 40,268, who together constitute the firm of WENDEROTH, LIND & PONACK, L.L.P., as well as any other attorneys and agents associated with Customer No. 000513, to prosecute this application and to transact all business in the U.S. Patent and Trademark Office connected therewith.

I hereby authorize the U.S. attorneys and agents named herein to accept and follow instructions from Bryn & Aarflot AS as to any action to be taken in the U.S. Patent and Trademark Office regarding this application without direct communication between the U.S. attorneys and myself. In the event of a change in the persons from whom instructions may be taken, the U.S. attorneys named herein will be so notified by me.

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I further declare that all statements made herein of my own knowledge are true, and that all statements on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

1st Inventor Arc LUND Date 2000-05-29  
 2nd Inventor David LYSNE Date 2001-06-21  
 3rd Inventor Roar LARSEN Date 2000-06-04  
 4th Inventor Kai W. HJARBO Date 2001-06-18  
 5th Inventor \_\_\_\_\_ Date \_\_\_\_\_  
 6th Inventor \_\_\_\_\_ Date \_\_\_\_\_

The above application may be more particularly identified as follows:

U.S. Application Serial No. \_\_\_\_\_ Filing Date April 19, 2001

Applicant Reference Number 104103/G/JE Atty Docket No. 2001 0396A

Title of Invention METHOD AND SYSTEM FOR TRANSPORTING A FLOW OF FLUID HYDROCARBONS CONTAINING WATER